Range-Dependent Acoustic Propagation in Shallow Water with Elastic Bottom Effects

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LONG-TERM GOALS

The long-range objectives of this research are to develop efficient accurate tools for quantitative forward modeling in range dependent, bottom-interacting acoustic propagation including sediment anisotropy and anelasticty.

OBJECTIVES

The specific objectives of this research are to develop practical theoretical and software tools for employing a fully elastic version of two-way coupled modes for modeling seismo-acoustic signals in shallow water with realistic elastic bottom properties, that may extend to elastically anisotropic sediment cover.

The work under award #N00014-14-10627 has been carried out with the collaboration of Dr. Scott Frank, Marist College, NY, and Dr. Jon Collis, from the Colorado School of Mines. Both were funded separately, and are not covered by this report.

APPROACH

The Call for Planning Letters suggested interest in acoustic frequencies as low as 10 Hz. This frequency corresponds to a wavelength of 200 m for a sediment compressional speed of, say, 2000m/s. At such low frequencies acoustic penetration into sediments is significant. Elastic effects (shear) cannot be ignored. In addition ocean sediments are often elastically anisotropic by the very mechanisms by which they are formed. If the anisotropy is significant, horizontally polarized shear waves (SH) can be generated even from an explosion source in the water. This conversion to SH is required by the boundary condition at the interface between the water and sediments at the ocean bottom. The attenuation in near-bottom ocean sediments may be very high. It may be high enough that perturbation theory is inadequate for properly describing loss in shallow water acoustic propagation. Finally there is range dependence, which can be significant in littoral regions. This project addresses two of these shallow water issues.

Range Dependence: We know that range dependence can couple (scatter) modes. In the presence of anisotropy, range dependence and anisotropy reinforce the scattering so that all modes P-SV and SH all couple together.

Anisotropy: Our local mode model incorporates anisotropy with hexagonal anisotropy, but an arbitrary symmetry axis. By incorporating this into a time domain range dependent code we will be able to trade off the effects of range dependence and anisotropy in the modeling. Much of the trade-off work has been done locally, and appeared in JASA (Soukup et al., 2013).

WORK COMPLETED

In the last year "Elastic parabolic equation solutions for oceanic T-wave generation," Frank et al., has been published. This article documents the incorporation of seismic-like sources into the PE propagation model work important for ocean acoustic signals referred to as T-phases. A short note titled "Modeling explosion generated Scholte waves in sandy sediments with power law dependent shear wave speed" by Alexander G. Soloway, Peter H. Dahl, and Robert I. Odom is *in press* with JASA-EL. Odom's contribution to this were supported by this grant. Finally the paper "Traveling wave modal attenuation and interaction with a transversely isotropic viscoelastic layered Earth model" by R.I. Odom has been submitted to *Geophysical Journal International*.

RESULTS

The two papers published and one submitted this year contribute to our understanding of seismo-acoustic propagation process in the ocean environment. Oceanic T-phases are naturally occurring, ubiquitous in the ocean, and a significant source of very low (~10Hz) noise in the ocean. They are excited by seismic activity in and around the ocean basins. An important step in understanding them is a proper representation of the seismic sources in the sound propagation models, which the Frank et al. paper describes.

Soloway and Dahl carried out an experiment using explosives to generated Scholte waves in sediments. My part of the effort was assistance with the theoretical interpretation of the data.

Finally attenuation is often treated in modal models using perturbation theory. This is fine if the losses are fairly small. Seismologists have noted that when the attenuation is large, treating the attenuation with perturbation theory leads to demonstrable errors in mode sum propagation models. Because the problem is with the eigenfunctions themselves, just going to higher order in perturbation theory does not solve the problem. Representing the seismo-acoustic signal for the strongly attenuating medium as a superposition of modes of the perfectly elastic medium leads to a quadratic generalized eigenvalue problem, which may be exactly converted to a linear generalized eigenvalue problem. This is the topic of the third publication produced from this year's work.

IMPACT/APPLICATIONS

This work will lead to a practical method to investigate seismo-acoustic propagation in shallow-water environments, and allow us to compare and contrast various environmental effects on the seismo-acoustic wave-field.

RELATED PROJECTS

Our research is directly related to other programs studying effects of propagation at low frequency bottom-interacting sound.

PUBLICATIONS FY15

Frank, S., J. Collis, and R.I. Odom, "Elastic parabolic equation solutions for oceanic T-wave generation"*J. Acoust. Soc. Am.*, 137, No.6,pp3534-3543, DOI – 10.1121/1.4921029.

Soloway, A.G., P.H. Dahl, R.I. Odom, "Modeling explosion generated Scholte waves in sandy sediments with power law dependent shear wave speed," *J. Acoust. Soc. Am. - EL,* IN PRESS*,* August, 2015

Odom, R.I. "Traveling wave modal attenuation and interaction with a transversely isotropic viscoelastic layered Earth model," *Geophysical Journal International*, SUBMITTED.